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Groundwater Contamination and Contingent Valuation of Safe Drinking Water in Guadalupe, Zacatecas, Mexico

by

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Groundwater Contamination and Contingent Valuation of Safe Drinking Water in Guadalupe, Zacatecas, Mexico

Osiel González Dávila [1]

Abstract

Guadalupe municipality, located in a semi-arid zone, belongs to the State of Zacatecas in north-central Mexico. The population in Guadalupe has been increasing in an exponential way from the year 2000 to 2010. With a bigger population in the area more services are required, including water supply and sanitation. Guadalupe depends on groundwater for its domestic water supply. It has no access to surface water and its aquifers are overexploited. There is a high risk that in the near future the population's water demand could not be satisfied. Therefore groundwater protection should be a priority. High levels of fluoride and arsenic have been found in extraction wells and in tap water in Guadalupe City. This may seriously affect the population's health. An exploratory study found statistically significant correlations between the presence of arsenicosis and fluorosis symptoms and the consumption of certain food items and tap water. A contingent valuation survey is used to elicit household willingness to pay responses for safe drinking water in Guadalupe. The objective is to investigate households' willingness to pay for improved water quality through the installation of a new filtration system to remove fluoride and arsenic from groundwater. It was found that individuals' subjective perceptions of contamination may change their attitude towards the installation of water purification systems, thereby changing the effective price of potable groundwater that they are willing to pay. It is evident that different types of contamination (by arsenic and fluoride in this case) had differing effects on values. Value estimates also changed as the socioeconomic profiles of survey respondents changed. Further, it was found that the respondents stated in average a higher WTP for the removal of fluoride (MXN 66.37) than for the removal of arsenic (MXN 56.55).

JEL classification: Q51, Q53

Keywords: Groundwater contamination, Arsenic, Fluoride, Contingent Valuation, Zacatecas Mexico.

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Introduction

Groundwater plays a very important role for Mexican economic activities and welfare. There are 653 aquifers and, on average, groundwater extraction provides more than 60% of the national water supply (CONAGUA 2010:68). Arsenic (***As***) and fluoride ($\boldsymbol{F^{-}}$) have been identified among the most severe inorganic contaminants present in groundwater worldwide (Fawell and Nieuwenhuijsen 2003, Ng et al. 2003). Exploitation of aquifers containing toxic elements may increase their concentration and seriously affect the population's health (Armienta and Segovia 2008:345). Groundwater ***As*** and $\boldsymbol{F^{-}}$ levels above the limits established by the Mexican Official Norm (***MON***) have been detected in several areas of Mexico, mainly within the states located on a mineralized belt that crosses from the northwest to the south of the country (Armienta *et al* 2010:61).

According to the National Commission of Water, the total population living in states where there is systematic information about high levels of ***As*** and/or $\boldsymbol{F^{-}}$ in the waterworks is 6.4 million people (Vega 2001:3). In Mexico, the association between consumption of water containing high levels of ***As*** and $\boldsymbol{F^{-}}$ and adverse health outcomes has been demonstrated in various epidemiological studies (see for example Cebrián *et al.* 1994, Del Razo *et al* 1999, and Armienta *et al* 2010). Armienta and Segovia (2008:351) state that the results of these investigations have prompted the water authorities in some of the affected areas of Mexico to supply water from non- contaminated sources. Nevertheless, these studies have been conducted only in few zones. Therefore, the exposed population may be larger than that already identified and there is an urgent need to conduct similar studies in all contaminated areas.

In Mexico, the socio-economics of groundwater arsenic and fluoride occurrence is little studied, although it appears that awareness is lacking. To overcome this, a baseline survey in two potentially affected municipalities of Zacatecas, Mexico was undertaken to understand the level of awareness, health impact and potential arsenic and fluoride avoidance strategies. Water samples from extraction wells supplying water to those municipalities were collected and tested for ***As*** and $\boldsymbol{F^{-}}$ as part of this exploratory study.

The rest of the document is organised in the following way: Sections 1 and 2 describe fluoride and arsenic features and their impact on human health. Guidelines and standards both in Mexico and worldwide are also discussed there. Sections 3 and 4 present a brief review of the Fluorite and Arsenic mining activities in Mexico and the specific mining activities in the state of Zacatecas. Section 5 presents the methodology and result of the exploratory study. Section 6 presents the contingent valuation study. Conclusions and policy recommendations are offered in the last section.

1. Fluoride

Fluorine (***F***) is a poisonous gaseous element. In the periodic table of elements it is located in the halogen group (group VIIB). ***F*** is one of the most reactive chemical elements. Therefore, it is not found free in the environment. It has a strong tendency to acquire a negative charge and in solution forms fluoride (F^-) ions. Thus, fluorine in the environment is found as fluorides. Hydroxide ions have the same charge and nearly the same radius as F^- ions and in mineral structures may replace each other. Thus, F^- forms mineral complexes and some common mineral species of low solubility contain F^- (Fawell *et al* 2006:5). In various places of the world, the presence of F^- in groundwater is a serious cause of morbidity. Dental fluorosis -an unsightly brown mottling of teeth- can result from high F^- intakes. Higher intakes can provoke skeletal fluorosis, which can lead to fractures and crippling skeletal deformity. Fawell and Nieuwenhuijsen (2003:203) report that "fluorosis can manifest itself at an early age with the result that affected individuals cannot work properly and may be economically as well as physically disadvantaged for life." Many factors appear to influence the risk of such adverse effects, including volume of drinking water, nutritional status and fluoride intake from other sources. High fluoride content of groundwater has caused teeth and bone diseases in San Luis Potosí and Aguascalientes states, both in Central México (Armienta and Segovia 2008:346).

1.1 Fluoride guidelines and standards

In 1984, the first edition of the World Health Organization (WHO) Guidelines for Drinking-water Quality stated that dental fluorosis is associated with fluoride levels in drinking-water above 1.5 mg/L. When ***F*** levels exceed 10 mg/L crippling skeletal fluorosis and an increased risk of bone fractures can result. Thus, a guideline value of 1.5 mg/L F^- was recommended as a level at which dental fluorosis should be minimal (WHO, 1984). The 1984 guideline value was re-evaluated in 1996 and 2004 and it was concluded that there was no evidence to suggest that it should be revised (WHO, 1996, 2004). However, the 1.5 mg/L F^- guideline is not a "fixed" value. If national standards for fluoride are set, they should be adapted to take into account the local conditions for example water intake, climatic conditions, and intake of $\boldsymbol{F^-}$ from food and air (WHO, 1996). In Mexico, a modification in the year 2000 of the Mexican Official Norm NOM-127-SSA1-1994 (SSA 2000:77) established at 1.5 mg/L the permissible limit of $\boldsymbol{F^-}$ in drinking water.

2. Arsenic

Arsenic (***As***) is a member of group VA of the periodic table and has the common oxidation states of –3, +3 and +5. The redox states of ***As*** are arsenite $\boldsymbol{As}^{III}$ (H_3AsO_3) and arsenate $\boldsymbol{As}^{V}$ (H_3AsO_4). ***As*** and its compounds are present in trace quantities in all rock, soil, water and air. However, concentrations may be higher in certain areas as a result of weathering and anthropogenic activities (WHO 2001:9 and Yu 2005:213). High ***As*** levels in drinking water may provoke skin, lung and bladder cancer and other adverse effects. Coetaneous changes due to arsenicosis include melanosis (patchy pigmentation of the skin), hyperkeratosis (thickening of the skin), desquamation and in severe cases gangrene. Anaemia and leucopoenia are highly related with chronic ***As*** exposure (Das, Mallick and Sengupta 2003 and WHO 2001). Epidemiological data demonstrate that many local factors are important, including nutritional status. Kozul *et al* (2009) reported that morbidity for mice exposed to influenza A (H1N1) -also known as *Swine Flu*- was significantly higher if they were also exposed to ***As*** contaminated water than otherwise. They concluded that ***As*** exposure disrupts the immune system and the endocrine system. In Mexico, the ability to have an immune response to influenza A (H1N1) infection was compromised by low levels of arsenic exposure from contaminated well water. It was noted that Mexico has areas of high arsenic in well water that include locations where influenza A (H1N1) was first identified (US Geological Survey 2011:21). The "Comarca Lagunera" is a metropolitan area located between the states of Coahuila and Durango in Northern Mexico. There, high levels of arsenic in drinking water were identified for the first time in 1958 as the cause of adverse effects on health (Cebrián et al. 1994). Arsenic levels above the Mexican drinking water standards have also been detected at other locations in Mexico.

2.1 Arsenic guidelines and standards

According to the last edition of the WHO Guidelines for Drinking–Water Quality (2006) ***As*** is considered to be a high–priority substance for screening in drinking–water sources. The current guideline value of 0.01 mg/L ***As*** was retained and designated as provisional since 1993. This value is higher in Mexico. From 1994 until the year 2000, the drinking water standard was 0.05 mg/L ***As.*** A modification to the Mexican Official Norm NOM-127-SSA1-1994 (SSA 2000:77) established since 2005 a guideline value of 0.025 mg/L ***As***.

3. Fluorite and Arsenic in mining zones of Mexico

Mexico is one of the most important arsenic and fluorite producers in the world due to the abundance of these elements in its subsoil. In 2010, Mexico occupied the sixth place in arsenic production (U.S. Geological Survey, 2011:20). Fluorite is one of the main non-metallic minerals exploited in Mexico, mostly in Coahuila, Durango, and San Luis Potosí states. In 2010 Mexico occupied the world's second place in fluorite production (U.S. Geological Survey, 2011:57). In many mining areas of Mexico ***As*** minerals occur in association with ores. Notable occurrences of ***As***-bearing minerals have been reported in various locations. Extraction and processing of ores may be a source of ***As*** contamination (Armienta and Segovia 2008:349). There is consensus in the literature that ***As*** and F^{-} groundwater contamination is related to mining activities. Mine tailings' environmental impact has been largely documented around the world. Deterioration and contamination of soils, groundwater and superficial water as well as alterations in the hydrological systems have been associated with mining wastes (Figueroa *et al* 2010).

4. Mining activities in Zacatecas

Zacatecas state is located in central north Mexico. There, metallic ores are abundant and diverse. The state has 450 years of mining tradition with the consequent accumulation of mining tailings (Salas–Luévano *et al* 2009). Zacatecas state is the most important silver producer in Mexico. Amalgamation for silver extraction, also known as patio process, consists in adding mercury to the silver ore in order to obtain a silver amalgam as the final product. Amalgamation was used extensively throughout the period from 1570 to 1820. Most of the heavy metals lost via amalgamation were carried by rivers and deposited in the plain areas of the Zacatecan valley in the Guadalupe County. Most of these areas are currently used for crop farming since there are no restrictions imposed by the Mexican authorities (Santos–Santos *et al* 2006). Numerous historic and present mine tailings are found throughout the state with thicknesses that range from less than one meter to ten meters (Castro *et al* 2003:255). Table 1 in appendix 2 shows the principal mining products in Zacatecas. The steady increase in silver and lead production and the exponential increase in gold production should be noted (see figures 1, 2 and 3 in appendix 2). Gold mining in Zacatecas could be identified as a potential source of ***As***-contamination of soils and water in the region. Gold mining activities discharge arsenic to the environment through waste soil and rocks, residual water from ore concentrations, roasting of some types of gold-containing ores to remove sulphur and sulphur oxides, and bacterially enhanced leaching (Eisler 2004:133).

4.1 Plants and soil contamination due to mining activities in Zacatecas.

In their exploratory study, Santos–Santos *et al* (2006) reported that the main source of heavy metal contamination in Guadalupe’s soil is related to old mining activities carried out in the surrounding area of Osiris and La Zacatecana. However, González Dávila, Gómez Bernal and Ruíz Huerta (2012) report that new mine tailings in the area are recklessly managed and there is an alarming lack of enforcement mechanisms to oblige the mining companies to obey the environmental laws and regulations. Those new tailings are a source of heavy metal contamination of the neighbouring agricultural land. High levels of arsenic, lead and mercury contamination in agricultural soil and plants were found in two irrigation zones. Two heavy metal exposition routes were identified. In the first place, there is a respiratory intake of particles and dust from contaminated soil. Second, there is a deposition of heavy metals in maize aimed for human consumption in the area. There is also a very high risk of aquifer contamination due to the presence of new tailing ponds in the area. However, more research needs to be done in order to confirm or reject the link between current and old mining activities and aquifer contamination.

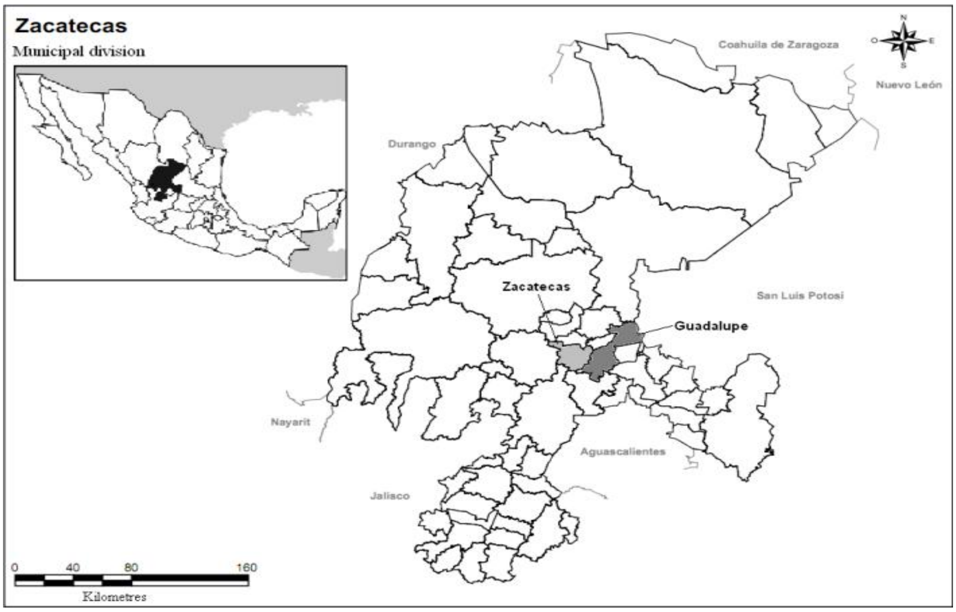
5. Exploratory study

In Mexico, the socio-economics of groundwater arsenic and fluoride occurrence is little studied, although it appears that awareness is lacking. To overcome this, a baseline survey in two potentially affected municipalities of Zacatecas, Mexico was undertaken. The study was conducted during September 2010. The aim was to understand the level of awareness, health impact and potential arsenic and fluoride avoidance strategies. Water samples from extraction wells supplying water to those municipalities were collected and tested for arsenic and fluoride levels as part of this exploratory study. The following sections explain in detail the methodologies employed.

5.1 Geographical delimitation of the study area

Zacatecas and Guadalupe are two municipalities of Zacatecas State in Mexico (see map 1). Zacatecas State is located in a semi-arid zone with an average annual precipitation of 463 mm (CONAGUA 2010:25). The average annual temperature is 17°C. The average maximum temperature is 30°C and occurs during May. The average minimum temperature is 3°C and occurs in January. Zacatecas municipality is located at 2,420 metres above sea level (lat 22° 46' N and long 102° 34' O). Guadalupe municipality is located at 2,280 metres above sea level (lat 22° 45' N and long 102° 31' O).

Map 1 Location of Zacatecas and Guadalupe municipalities in Zacatecas State



Source: INEGI. Marco Geoestadístico Municipal 2005

The information about altitude of the study area is crucial for understanding fluorosis morbidity in the region. High altitude has been established in the literature as an important risk factor for dental fluorosis. Several studies have found high prevalence and severity of fluorosis in communities located at 1,500 m above sea level. The results suggest that the higher the altitude, the less fluoride is required to cause enamel fluorosis (see for example Angmar-Mansson & Whitford 1990, Molina *et al* 1999, Cao *et al* 2003 or Soto Rojas *et al* 2004).

5.2 Demographic dynamics in the study area and sustainability of aquifers' exploitation

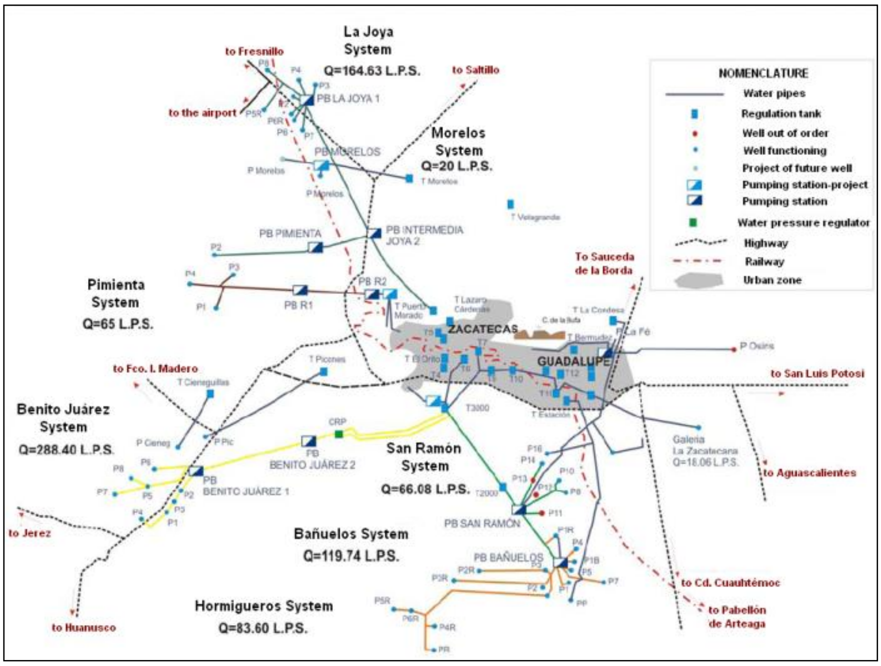
According to the National Institute of Statistics, Geography and Informatics (INEGI), in the year 2010 Zacatecas had 138,176 inhabitants and Guadalupe 159,991 inhabitants (INEGI 2010). The population in Guadalupe has been increasing in an exponential way from the year 2000 to 2010 (see figure 4 in appendix 2). According to the last census Guadalupe's population has exceed that of Zacatecas (where the capital city is located). With a bigger population in the area more services are required, including water supply and sanitation. Four aquifers supply water to the zone: Benito Juárez, Calera, Chupaderos and Guadalupe-Bañuelos. The overexploitation of aquifers provokes regional reduction of groundwater levels, dry wells, higher extraction costs, land subsidence and brackish groundwater. Table 2 in appendix 2 shows the unsustainable use of the aquifers in the study area. In all cases the groundwater extraction is higher than the average annual recharge. There is a high risk that in the future it would not be possible to satisfy the population's water demand. Another reason of concern is that exploitation of aquifers containing heavy metals may increase their concentration, and seriously affect the population's health (Armienta and Segovia 2008:345).

5.3 Identification of arsenic and fluoride levels in the water supply systems

Map 2 shows the water supply systems in the suburban area of Zacatecas and Guadalupe. They can be grouped into three systems. The first system is called "la Joya" or "Calera" and includes one extraction well from the "Pimienta" system and the "Morelos" system. The second system is called "Benito Juárez" and includes three extraction wells from the "Pimienta" system. The third system is called "Bañuelos-San Ramón" and includes the "Hormigueros" system. According to the volume of extracted water, in first place we find the

Benito Juárez system that produces 280.77 litres per second (40%); followed by the Bañuelos-San Ramón system that produces 254.84 litres per second (37%) and finally, La Joya system that produces 161.46 litres per second (23%). These systems operate 24 hours per day. The concentration levels of ***As*** in the extraction wells of the region is unevenly distributed and present variations over time. Castro *et al* (2003:259) measured water quality for 48 extraction wells of the three systems in 1994. They reported an ***As*** concentration range from 0.001 to 0. 4925 mg/L. Leal and Gelover (2002:80) sampled 10 extraction wells in the zone. 40% of the samples were above the Mexican guideline of 1.5 mg/L F^-. 80% of the samples were above the 2005 Mexican guideline of 0.025 mg/L ***As.***

Map 2 Water supply systems in the Zacatecas – Guadalupe zone



Source: Rivera (2010:18)

After analysing the data reported in Leal and Gelover (2002), the San Ramón system was identified as the most problematic water system in the region. Thus, it was decided to collect water samples from the extraction wells of the whole system. Ten samples from the extraction wells San Ramón 8, 10, 14, 16 and "la Coruña" were collected following the methodology in the Mexican Official Norm and tested for ***As*** and F^- in the Laboratory of Analytical Chemistry at the Geophysics Institute of the National Autonomous University of Mexico (UNAM). The results are shown in table 3 in appendix 2. In relation to ***As***, extraction well 16 is ten times above the current ***MON*** while extraction well 14 is sixteen times above the guideline. It should be noted that there is a documented variation overtime of both ***As*** and F^- contents. Table 4 in appendix 2 shows historical ***As*** levels in wells 14 and 16. Table 5 in appendix 2 shows historical $\boldsymbol{F^{-}}$ levels in wells 14 and 16. There is an evident increase of the $\boldsymbol{F^{-}}$ levels in such wells. Castro *et al* (2003) report that extraction wells with high ***As*** contents were closed. However, extraction wells 14 and 16 in the San Ramón system (historically showing high levels of ***As*** and $\boldsymbol{F^{-}}$) were operating normally during the water-sampling period in September 2010. The researcher was informed that extraction well 13 was also fully operating, but permission for taking a sample was denied. Neither Zacatecas municipality nor Guadalupe municipality have ***As*** and/or $\boldsymbol{F^{-}}$ water treatment plants. During the fieldwork it was found that the local water authorities mix water from highly contaminated wells with water from others less contaminated as a method to reduce the levels of ***As*** and $\boldsymbol{F^{-}}$ in the water supply of the region. This method has also been implemented in other water arsenic contaminated areas like Comarca Lagunera and Zimapán, Hidalgo (García *et al* 1994, Armienta and Segovia 2008). In order to evaluate the tap water quality, eight water samples were collected from households in Guadalupe and Zacatecas cities and were tested for ***As*** and $\boldsymbol{F^{-}}$ (see table 3 in appendix 2). All the samples but one are above the ***As*** and $\boldsymbol{F^{-}}$ Mexican guideline. All the tap water collected in households belonging to suburban areas of both municipalities have ***As*** concentrations above the WHO guideline of 0.01 mg/L but under the ***MON*** guideline of 0.025 mg/L.

5.4 Structural Questionnaire for Quantitative Analysis

Primary data was obtained through a pre–tested standardized structural questionnaire for quantitative analysis. The aim of the survey was to understand the level of arsenicosis and fluorosis awareness, health impact and potential ***As*** and $\boldsymbol{F^{-}}$ avoidance strategies of the population in the study area. The collection of primary data was done through personal interviews conducted face-to-face. The interviews were conducted by the researcher aided by a Mexican research assistant educated at post-graduate level. Training on identification of fluorosis and arsenicosis symptoms was provided. A stratified random sampling strategy was used to select the households to be interviewed. Guadalupe municipality was visited first. Because of the nature of the questionnaires only individuals 18 years old or above were interviewed, preferably the head of household or a mature respondent if the head of household was not available or if the respondent was contacted outside the household. According to the 2010 Population Census (INEGI 2010), the total population in Guadalupe and Zacatecas municipalities is 298,167 inhabitants. The required sample size[2] was 184 questionnaires.

5.5 Survey structure

The survey is divided into eight sections. The first section records the time and place of the interview and the number of years that the respondent has lived in the municipality. Only respondents living in Zacatecas and Guadalupe municipalities were interviewed. The second section records the individual details of the respondents: their age and sex. Social information like the marital status of the respondent, the number of household members and the number of children 14 years old and younger were captured in section three. Seven variables were selected for registering economic information in section four. Monetary and non-monetary factors that impact the household income were considered. The level of education was included because a higher education level usually is correlated with higher income. The respondent's main economic activity was also asked. The five monetary variables included are: household income, household monthly expenditures on food, in medicine, in bottled water and in household water. All the monetary variables are expressed in Mexican pesos.[3] Section five gathers information about water supply features. Three variables were considered to differentiate the water supply sources according to its use: drinking water, cooking water and other uses water. It was also asked if the household owns a water filter and the brand of such filter. Finally, it was asked if the respondents have noticed a change in colour or flavour in the tap water in the last three years. The aim of section six is to identify the water consumption patterns in the study areas. Two variables were considered. At individual level the amount of drinking–water glasses consumed per day. It was explained to the respondents that the size of the glass should be one of approximately 250 millilitres. At household level the average litres of water used for cooking per day. Section seven aims to assess the respondent's knowledge of arsenicosis and fluorosis symptoms and the household health status. Questions relative to the presence of brown mottling of teeth (fluorosis

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[2] It was calculated using the following formula:

$$1)\ n \geq \frac{N\left(\frac{z}{2e}\right)^2}{N - 1 + \left(\frac{z}{2e}\right)^2}$$

Where n represents the sample size, N the population, z the z–score and e the error, and considering margin of error of less than 10% at a 99% confidence level.

[3] In 2012, in average 1 US Dollar =13.17 Mexican Pesos.

symptom) and the presence of dark spots on the hand palms (arsenicosis symptom) of household members were posed. Information about access to health services was also collected. Finally, section eight recorded weekly food consumption patterns in relation to the following items: soup, beans, chicken soup, stew, coffee and atole. Such items are of particular interest. It was thought that they could increase the risk of fluorosis and/or arsenicosis symptoms if ***As*** and $\boldsymbol{F^-}$ contaminated water was used in their preparation.

5.6 Survey results and discussion

Table 6 in appendix 2 shows the average profile of sampled households. As previously explained only individuals 18 years old or above were interviewed. The respondents' average age is 38 years. This average is consistent with the survey design because normally mature people are responsible for the household administration. The highest proportion of respondents is concentrated in the 18–29 age group (37.5%), while the lowest is in the group 50-59 years (9.78%). The survey is well balanced in relation to the respondents' gender. The percentage of female and male respondents is almost equal: 49% and 51% respectively. In relation to the marital status of the respondents, almost sixty percent are married. This is consistent with the age groups found in the sample. The average number of household members is 4.48 and, on average, there is one child under 14 in each household. This information is important because research has found that children under 14 are at the highest risk of showing fluorosis symptoms. In average the respondents have 9.22 years of schooling. The average household income is $4,496. The average monthly expenditure in food is $1,573. This means that approximately one third of the household income is used in buying food. The average monthly expenditure in medicines is $171. It should be noted that 73% of the respondents stated that they have access to health services provided by the state and most of such services provide medicines. The average monthly expenditure in household tap water is $91. The average monthly expenditure in bottled water is $104. This is an interesting result because expenditure in bottled water can be understood as a proxy of the average household willingness to pay for clean and safe water. The fact that the budget share of bottled water is higher than the budget share of tap water is an indicator that the households in the region do not trust the quality standards of the local water provider. Further, 57.61% of the interviewees stated that in the household they only consume bottled water. 18.78% of the respondents stated that tap was their only drinking water supply. The rest of the respondents use a combination of filters, bottled water and tap water. In contrast, 47.48% of the interviewees reported that in their households they only use tap water for cooking and 33% of the respondents use only bottled water for cooking. 27 out of 184 respondents have water filters in their household. However, the household filter brands available in the regional market are not adequate for removing fluoride and heavy metals. The mistrust in the quality of tap water could be related to the fact that almost half of the respondents reported changes in the colour (brown or white) and/or flavour (strong chloride or soil flavour) of their tap water in the last 3 years. Nevertheless, access to tap water and water storage tanks is very high. It should be highlighted that 99.5% of the respondents have access to tap water, 43 households in the sample have a water cistern and 164 have water tanks.

In terms of water consumption, the respondents declared that on average their household requires 4.3 litres of water for cooking. One of the most striking findings is that although toxic ***As*** levels have been found in the water extraction wells of the region (see Leal and Gelover 2002 and Castro *et al* 2003), the population is not aware of this. 78% of the interviewees do not know what arsenic is. 90% do not know the disease caused by arsenic (arsenicosis) and 98% do not know the arsenicosis symptoms. Nevertheless, 18.48% of the respondents reported at least one household member with dark spots on the hand palms (arsenicosis symptom). In relation with fluorosis, the situation is not much different. Only 10% of the respondents know what is fluorosis, 7% of the respondents can identify the fluorosis symptoms and only 4% know how to avoid it. Finally, 41.3% of the respondents stated that at least one household member shows brown mottling of teeth (fluorosis symptom). This was verified by the interviewers directly on 44 respondents. In view of the high levels of fluorosis found among the population, it was thought that there might be other sources of exposure to fluoride like fluoridated salt. Thus, a complementary survey was conducted asking to 112 people if the salt that they use for cooking is fluoridated. A modification to the Mexican Oficial Norm NOM-040-SSA1-1993 established that flouridated salt should not be distributed in Zacatecas State (SSA 2003). Nevertheless, 9% of the respondents said that they use fluoridated salt for cooking. Further, the researcher found that local retailers sell fluoridated salt.

A fluorosis dummy variable (***FDV***) was used to conduct correlation analysis (the variable takes the value of 1 if the household has at least one member with fluorosis symptoms and 0 otherwise). The results of the correlation analysis show that the presence of brown mottling of teeth in at least one household member is positively correlated with the type of drinking water supply (corr. coef. 0.167) and the type of cooking water supply (corr. coef. 0.261). A positive and statistically significant correlation between ***FDV*** and the litres of water used for cooking was also found (corr. coef. 0.146). An arsenicosis dummy variable (***ADV***) was used to conduct correlation and regression analysis (the value of 1 was associated if the household has at least one member with arsenicosis symptoms and 0 otherwise). The correlation analysis results suggest that the presence of black spots on the hand palms is positively correlated with the litres of water used for cooking in the household (corr. coef. 0.161). A second very important result was found in another correlation coefficient that shows that beans consumption is positively correlated with the presence of black spots on the hand palms of at least one household member (corr. coef. 0.192). Thus, more research is needed to find out agricultural practices that could be leading to this outcome (for example, the use of ***As*** contaminated water for irrigation or the presence of ***As*** contaminated soil in farming areas). Due to the limitations of the survey data to disentangle the potential determinants of health outcomes, it is necessary to conduct a more detailed epidemiological study in the future.

6. Contingent Valuation of Safe Groundwater in the city of Guadalupe.

In view of the results of the exploratory study, it was decided to conduct a contingent valuation of safe and reliable groundwater supply. Guadalupe depends on groundwater for the supply of domestic water and groundwater protection must be a priority. In order to ensure the quality of the groundwater over time, it is necessary to develop a filtration system to remove fluoride and heavy metals.

6.1 Theoretical Framework and modelling approach

A utility-theoretic framework for consumer responses to improvements in water quality and system reliability is provided in this section. Suppose that $v(y, w, p, z)$ is the indirect utility function of a household that increases with income (y) and positive attributes of water services (w). Vector w contains different attributes (for example, quality and reliability of tap water provision) relevant to the provision of water services. Indirect utility v, decreases with prices of other goods (p), and is also affected by the household's features (z). Hence, the household will be willing to pay for water service improvements up to the extent that this payment does not decrease their utility below the original utility level. Thus, a Hicksian surplus (the household maximum willingness to pay (WTP) for any improvement in water services for example the installation of a new filtration system to remove fluoride and arsenic from groundwater) is defined as:

1) $v(y, p, w_0, z) = v(y - wtp_1, p, w_1, z) = v(y - wtp_2, p, w_2, z)$

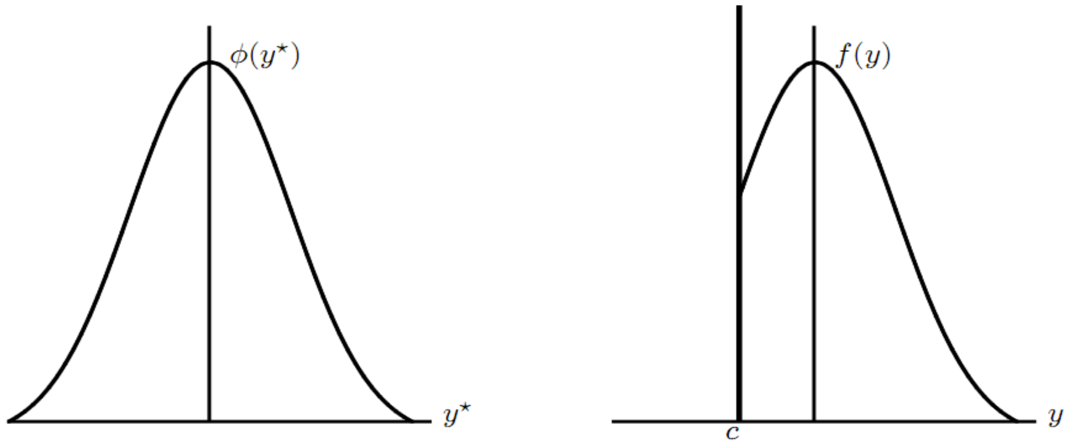
where, (w_0) represents the current provision of water services, (w_1) represents improved quality of drinking water under the proposed project (i.e., the increment in only water quality), and (w_2) represents some separate additional improvement in water services, such as system reliability. A household's WTP for water services is a function of these multidimensional water attributes: income, prices of other goods, and other relevant household characteristics. Given that (w_1) and (w_2) represent separate improvements, then *wtp* for the combined improvement $(w_1 + w_2)$ (i.e., wtp_{1+2}) would be greater than the WTP for the water quality improvement alone (w_1) (i.e., $wtp_{1+2} > wtp_1$). Following Carson and Mitchel (1995), this provides a test of scope for a nested good.

In the contingent valuation literature, Ordinary Least Squares (OLS) regressions are commonly used to estimate a WTP model from responses to an open-ended question. However, if the sample is censored it is not appropriate to use OLS. A censored value can be defined as follows. Let y^* be a normally distributed variable with mean μ and variance σ^2. An observed variable is censored below if:

$y = c$ if $y^* \leq c$ and $y = y^*$ otherwise.

where c is a given constant. This is illustrated in the following figure:

Figure 5 Normal Variable y* and Censored variable y



During the fieldwork, various zones in the city reported that tap water services were interrupted for at least two weeks before the interview. Given that a number of WTP observations have a zero value (protests for the unreliable water supply), the sample is censored. Therefore, the proper model for assessing the WTP is a Tobit model. Thus, the structural equation in the model is:

2) $wtp_i^* = X_i\beta + \epsilon_i$

Where wtp^* stands for the household's willingness to pay for a change in the public water system, X is a vector of covariates, which could include treatment variables (e.g., indicating different levels of scope, or provision rules, concerning water services), household income and additional characteristics, β is a conformable vector of relevant coefficients to be estimated, and ϵ is the stochastic error term. It is assumed that $\epsilon_i \sim N(0, \sigma^2)$. Further, wtp^* is a latent variable that is observed for values greater than τ and censored otherwise. The observed *wtp* is defined by the following measurement equation:

3) $wtp_i = \begin{cases} wtp^* & if\ wtp^* > \tau \\ \tau_{wtp} & if\ wtp^* \leq \tau \end{cases}$

In the typical tobit model, we assume that $\tau = 0$ i.e. the data are censored at 0. Thus, we have

4) $wtp_i = \begin{cases} wtp^* & if\ wtp^* > 0 \\ 0 & if\ wtp^* \leq 0 \end{cases}$

6.2 Data collection mode and sample size

A contingent valuation survey was used to elicit willingness to pay responses for safe drinking water at household level. The collection of primary data was done through personal interviews conducted face-to-face. Provision of information on the item being valued is a fundamental component of a contingent valuation survey. Personal interviews have the highest ability because visual information is provided and the interviewer is available to explain the information and answer questions. Guadalupe city is the capital of Guadalupe municipality. According to the 2010 census, it has 124,623 inhabitants (INEGI 2010). Considering a margin of error of 8% and a 95% confidence level, the required sample size[4] was 150 questionnaires. It was decided to conduct 300 questionnaires in total to allow the identification of 2 subsamples of 150 questionnaires each. A stratified random sampling strategy was used to select the households to be interviewed. The survey was pretested and implemented in June 2011 and February 2012. Face-to-face interviews were conducted by the researcher aided by a Mexican research assistant educated at post-graduate level who had previous experience in other research projects. Training on identification of fluorosis and arsenicosis symptoms was also provided.

6.3 Design of the information component of the survey instrument

The survey instrument consists of six sections. The first section records the time and place of the interview and the number of years that the respondent has lived in the municipality. Only respondents living in Guadalupe city were interviewed. The second section records socio-demographic characteristics of the household. In the third section, respondents are asked to evaluate the current water system. Respondents were asked to rate the current tap water quality on a five-point scale, with 1 being “very poor” quality and 5 being “very good” based on taste, odour, and colour. In the fourth section, respondents report on their consumption of substitute goods (bottled water and filtered water). Here is also asked to respondents to specify the main reasons for purchasing bottled water or using a water treatment device. Three options were offered: Taste, health concerns and other reasons. In all three cases it is required that the respondent elaborate on her answer. In the fifth section, sampled households report their expenditures on food and both tap and bottled water. The sixth section includes

[4] The sample size formula used here is the same as that used in section 5.

the valuation component of the survey and a follow-up question. After presenting the contingent scenario, each respondent was presented with an open-ended valuation question. The base good valued in the referendum presented to all respondents is provision of safe drinking water (free of fluoride or free of arsenic), at the tap, to households in Guadalupe and included the installation of a new filtration system. Individuals' subjective perceptions of contamination (by fluoride and arsenic in this case) may change their behaviour in that the households purchase in-house water purification systems or bottled water thereby changing the effective price of potable groundwater. Therefore, the experimental design included a four split-sample treatment (2x2), with variations in the full good provided, and in the quality of provision for implementing the good. The split-sample variation in the good allows for a scope test for a ‘‘nested’’ good. The provision of safe drinking water varied among respondents in two split-sample levels:

(a) Water fluoride removal
(b) Water arsenic removal

Then, crossed in the 2x2 experimental design, two different types of quality provision were also randomly assigned to split samples: (a) complete or incomplete arsenicosis and/or fluorosis symptoms reduction (following the WHO/MON guidelines) (b) reliable water provision (24/7) or the current unreliable water provision. Sampled households were randomly assigned one of the four treatments. In the valuation section, the characteristics of the existing water system are described and an improvement in the provisions of safe drinking water is presented, which varies the reliability of the water supply and the quality of provision across respondents according to the experimental design. The Inter-municipality Board of Drinking Water and Sewerage is the public institution in charge of the water management in Zacatecas. It was explained that the extra fee would be collected through the normal water fee receipt. Respondents were reminded that money spent on this additional fee will not be available for other household expenses. The WTP and graphic materials are included in the annex A.

6.4 Results and analysis

Tables 10 and 11 show the interviewees' characteristics. The respondents' average age is thirty eight years. The average age is consistent with the survey design because normally mature people are responsible for the household administration. In average the interviewees reported that they have lived in the municipality for 23 years. The average number of household members is 4.33 and at least one household member is a child under 14. The average monthly household income is 5,156.81 Mexican Pesos. The average monthly expenditure in food is 2,580.47 Mexican Pesos. The previous figures suggest that an average household use 50% of its income in food consumption. The survey is well balanced in relation to the respondents' gender. 56% of the respondents are female. 16% of the respondents stated that in their households they drink tap water. However, 44% of the respondents stated that they use tap water for cooking. 84% of the respondents stated that in their households they purchase bottled water. This fact suggests that most of the people do not trust the quality of tap water. An average household consumes more than 2 bottles of water per week and spends around 47 Mexican Pesos monthly in the bottled water purchases. In Zacatecas, the standard water bottle has a capacity of 20 litres. The average monthly expenditure on tap water is 128 Mexican Pesos. The differences with the figures obtained in the exploratory study are explained by the differences in tap water fees and bottled water consumption patterns in both municipalities. Table 12 presents the estimated WTP using the Tobit model.

Table 10 Average profile of a sample respondent (a)

Description	As		F		All	
	Mean	SD	Mean	SD	Mean	SD
Age of the respondents	37.90	13.52	37.29	13.79	37.60	13.66
Years living in the municipality	22.51	15.37	22.69	16.32	22.60	15.85
Household members	4.21	2.02	4.45	1.88	4.33	1.95
Children under 14	1.26	1.24	1.07	1.14	1.16	1.19
Household Income	5160.00	3738.30	5153.62	3454.86	5156.81	3596.58
Expenditure in food	2624.33	1729.11	2536.60	1538.11	2580.47	1633.61

Table 11 Average profile of a sample respondent (b)

Description	As	F	All
Percentage of female respondents	51	61	56
Percentage of households who drink tap water.	18	14	16
Percentage of households who cook with tap water.	40	47	43.5
Percentage of households who purchase bottled water	82	86	84
Average number of bottles of water consumed per week	2.53	2.79	2.66
Monthly expenditure on bottled water	44.68	49.49	47.085
Monthly expenditure on tap water	121.20	134.28	127.74

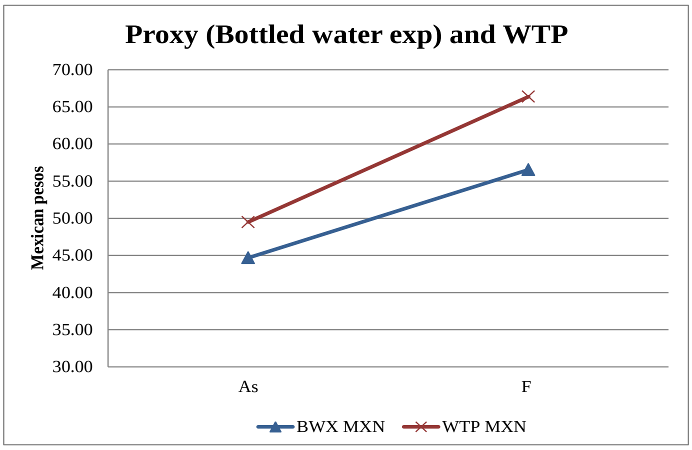
Table 12 Estimated Willingness to Pay (WTP) Models

	Variable	tbAs	tbF
Model			
	Sex	-19.77	-30.28**
	Age	-1.10*	-0.2
	Education	9.27*	11.15**
	HouseMembers	-9.95**	-8.61*
	Children	12.65*	22.83***
	Reliable	12.33	-5.49
	SymptomsRed	0.69	36.26**
	FoodExp	7.01	-0.18
	_cons	71.87*	53.99
Sigma	_cons	88.70***	81.57***
Statistics			
	N	146	150
	ll	-698.97	-774.19
	chi2	16.83	27.92

legend: * p<.1; ** p<.05; *** p<.01

The variables considered to explain the WTP are sex, age, years of education, number of household members, presence of children in the household, water supply reliability, complete or incomplete reduction symptoms reduction and level of income. In the case of the Arsenic survey, the WTP is explained by the respondent's age (older people are more willing to pay), the respondent's education (respondents with more schooling years are more willing to pay), the number of household members (households with more members are less willing to pay) and by the presence of children in the household (evidence of altruistic behaviour). In the case of the Fluoride survey, the WTP is explained by the respondent's gender (men are more willing to pay), the respondent's level of education, the number of household members, the presence of children in the household and by the level of symptoms reduction offered (if a complete reduction was offered they were more willing to pay). Food expenditure was used as a proxy for household income because the respondents were reluctant to reveal their household income. This variable seems to have no effect on the WTP for clean water.

Fig 6 Information effects



	BWX MXN	WTP MXN
As	44.69	56.55
F	49.49	66.37

Figure 6 presents the average WTP for the removal of As and F^- as well as the average expenditure in bottled water in the sub samples. As it was explained in section 5, the expenditure in bottled water can be interpreted as a proxy for WTP for clean and safe water. It should be noted that in both sub-samples the stated WTP is higher than the proxy. This is evidently an information effect. Households are more willing to pay for clean and safe water once they are informed about the arsenic and fluoride levels in the tap water and their effects on health. It is interesting to note that the respondents are more willing to pay for the removal of fluoride (66.37 MXN) than for the removal of arsenic (56.55 MXN). This could be linked to the fact that they could easily recognise the symptoms showed in the pictures (see Picture 3: fluorosis effects in appendix 1). It should be noted that in Mexico very few contingent valuation studies for safe groundwater have been conducted. In the only similar study carried out by Vazquez *et al* (2009) in Parral, Chihuahua, they report that 48% of the tap water samples in cities of Chihuahua (including Parral) exhibited radon concentrations above the standard set by the United States Environmental Protection Agency (US EPA) of 11 Bq/L. In their study they found for an open ended WTP question that people are willing to pay 111.31 MXN for safe drinking water. This is almost twice the WTP for the removal of fluoride and arsenic in Guadalupe.

6.5 Discussion

The exploratory and contingent valuation studies show that households in Guadalupe conduct private investment and different averting activities in order to deal with interrupted water supply and the (partial) perception of poor quality tap water. The results show a significant household WTP for improved water services because in general the households consider that the current water system is unreliable and unsafe. Households' investment in private infrastructure development include roof and ground water tanks, cisterns, etc. in order to have uninterrupted access to tap water (this could explain why offering water reliability was not significant in our models). Bottled water is also commonly purchased for drinking and cooking purposes, and a number of other household-based activities are applied to treat tap water. It is evident from these practices that there is a demand for more safe and reliable water services in Guadalupe. It was found that the average tap water fee is MXN 128. The results also indicate that the households have an average WTP of MXN 61 for safe and reliable drinking water. This is equivalent to an increase of 50% above the average water fee. Combined with current tap water expenditures, this increase in monthly water bills is equivalent to 1.19% of the reported average income. According the National Institute of Statistics (INEGI 2010) the number of inhabited households in Guadalupe is 41,783. Therefore, the monthly revenue for a fee increase of MXN 61 would be MXN 2,548,763. An arsenic filtration system constructed in 2011 in Zimapán Hidalgo required an investment of MXN 28,000,000 (CONAGUA 2011). It is considered that the required funding for the installation and operation of one plant in the region could be achieved in less than a year. However, increasing the water fees is not a straight forward solution. The water treatment plant can solve the contamination problem but not the scarcity problem. During the fieldwork several respondents complained about the frequent and long water supply cuts and argued that they are not willing to pay for a service that is not provided.

Conclusions

Due to Zacatecas geographical and climatic characteristics efforts should be done for a modification of the F^- 1.5 mg/l guideline value in the Mexican Official Norm. The fact that Zacatecas is located at high altitude increases the risk of fluorosis among its population. However this is not enough. There is a serious problem of enforcement and monitoring of environmental and sanitary laws and norms (for example the enforcement of the MON that prohibits the distribution of fluoridated salt). There is also a severe information problem. The population is not aware of the high levels of As and F^- in the tap water and the majority has no information concerning arsenicosis or fluorosis symptoms and the strategies to avoid them. Data about toxic element levels in the public water systems are not available to the public. Currently, households in Guadalupe conduct private investment and different averting activities in order to deal with interrupted water supply and the (partial) perception of poor quality tap water. There is a demand for more safe and reliable water services in Guadalupe. It is considered that the required funding for the installation and operation of a water treatment plant in the region could be achieved in less than a year and different sources of funding should be sought. However, higher water fees are not a definitive solution. The water treatment plant can solve the contamination problem but not the scarcity problem. During the fieldwork several respondents complained about the frequent and long water supply cuts.

The number of people affected with fluorosis and arsenicosis in the study area could be higher than already detected. Therefore, there is an urgent need for conducting more environmental, epidemiological and socio-economic studies in the area. Arsenic and fluoride must be determined in all groundwater sources in Zacatecas and Guadalupe municipalities on a regular basis. A comprehensive public strategy to tackle the problem is required.

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References

Angmar-Mansson B., Whitford G.M. (1990). Environmental and physiological factors affecting dental fluorosis. *Journal of Dental Research*, 69, Spec. No:706-13; discussion 721.

Armienta, M., Rodríguez, R., Segovia, N., and Monteil, M. (2010). Medical Geology in Mexico, Central America and the Caribbean. In O. Selinus et al. (eds.), *Medical Geology*, International Year of Planet Earth, Springer Netherlands. pp. 59 – 78.

Armienta, M. and Segovia, N. (2008). Arsenic and fluoride in the groundwater of Mexico. ***Environmental Geochemistry*** and ***Health, 30,*** pp. 345–353.

Cao, J., Zhao, Y., Liu, J., Xirao, R. and Danzeng, S. (2001). Varied ecological environment and fluorosis in Tibetan children in the nature reserve of Mount Qomolangma. *Ecotoxicology and Environmental Safety*, 48(1), pp.62-65.

Carson, R.T., and Mitchell, R. (1995). Sequencing and nesting in contingent valuation surveys. *Journal of Environmental Economics and Management , 28*, pp. 155 ‑ 173.

Castro, A., Torres, L. and Iturbe, R. (2003). Risk of aquifers contamination in Zacatecas, Mexico due to mine tailings. In Tailings and Minewaste ’03. Swets and Zeitlinger B.V., Lisse, The Netherlands. pp. 255 - 262.

Cebrián, M. E., Albores, A., García-Vargas, G., and Del Razo, L.M. (1994). Chronic arsenic poisoning in humans: The case of Mexico. In: J. O. Nriagu (Ed.), *Arsenic in the environment Part II* (pp. 93–107). New York: Wiley.

Comisión Nacional del Agua (CONAGUA) (2010). *Estadísticas del Agua en México, edición 2010*. México D.F.

CONAGUA (2009). Actualización de la disponibilidad media anual de agua subterránea. Estado de Zacatecas. Diario Oficial de la Federación. 28 de Agosto de 2009.

Das, H., Mallick, A., and Sengupta, P. (2003) Health Effects of Arsenic Contamination in Groundwater. In Rahman A., and P. Ravenscroft (Eds.) *Groundwater Resources and Development in Bangladesh, Background to the Arsenic Crisis, Agricultural Potential and the Environment* (pp. 419–433). Dhaka, The University Press Ltd.

Del Razo, L.M., García-Vargas, G., Hernández, M., Gómez-Muñoz, A. and Cebrián, E. (1999). Profile of Urinary Arsenic Metabolites in Children Chronically Exposed to Inorganic Arsenic in Mexico. In Chappell, W.R., Abemathy, C.O.and Calderon, R.L. (Eds.) Arsenic Exposure and Health Effects. Elsevier Science B.V., Amsterdam.

Eisler, R. (2004). Arsenic Hazards to Humans, Plants, and Animals from Gold Mining. *Reviews of Environmental Contamination and Toxicology*, 180, pp. 133–165.

Fawell, J. and Nieuwenhuijsen, M. (2003). Contaminants in Drinking Water. *British Medical Bulletin*, 68, pp. 199 – 208.

Fawell, J., Bailey, K., Chilton, J., Dahi, E., Fewtrell, L. and Magara, Y. (2006). *Fluoride in Drinking-water*. World Health Organization (WHO). IWA Publishing, London, UK.

Figueroa, F., Castro–Larragoitia, J., Aragón, A. and García–Meza, J. (2010). Grass cover density and metal speciation in profiles of a tailings-pile from a mining zones in Zacatecas, North-Central Mexico. *Environmental Earth Sciences*. 60 (2), pp. 395-407.

García, M.E.C, Medina, A.A., Câmara, V.M., Ramírez, D.G., Gotelli, C., Hopenhayn–Rich, C., Kosatsky, T., Romieu, I. and Vega, F. (1994). Metales Pesados. In Finkelman, J., Corey, G. and Calderon, R. (Eds.) *Epidemiología Ambiental: Un Proyecto para América Latina y el Caribe* (pp. 97–151). Environmental Protection Agency; ILO/UNEP/WHO International Programme on Chemical Safety. Metepec.
Instituto Nacional de Estadistica y Geografía e Informática (INEGI) (2010). Censos y Conteos de Población y Vivienda. The data are available in the following link:
http://www.inegi.org.mx/est/contenidos/Proyectos/ccpv/default.aspx [15/03/2011]

González Dávila, O., Gómez-Bernal, J.M, and Ruíz-Huerta, E.A. (2011). Plants and Soil Contamination with Heavy Metals in Agricultural Areas of Guadalupe, Zacatecas, Mexico. In Srivastava, J. (ed.) (2011). Environmental Contamination. InTech, ISBN 978-953-308-86-0 (In press).

Instituto Nacional de Estadistica y Geografía e Informática (INEGI) (2010). Banco de Información Económica. The data are available in the following link:
http://dgcnesyp.inegi.gob.mx/ [15/03/2011]

Kozul, C., Ely, K., Enelow, R. and Hamilton, J. (2009) Low Dose Arsenic Compromises the Immune Response to Influenza A Infection *in vivo*. *Environmental Health Perspectives*. 117(9), pp. 1441–1447.

Leal, M. and Gelover, S. (2002). Evaluación de la calidad del agua subterranea de fuentes de abastecimiento en acuíferos prioritarios de la región Cuencas Centrales del Norte. Anuario IMTA 2002.

Molina Frechero N., Mendez Ramirez I., Hernandez Guerrero J.C., Bologna Molina R. (1999). Dental fluorosis and altitude in Mexican and Uruguayan schoolchildren, ABSTRACTS from 3nd EADPH Congress, Strasbourg, France; Originally Published in *Community Dental Health* 16 (3) Div. Est Postgrado Facultad de Odontologia UNAM, UAM-X, IMAS-UNAM, Mexico.

Ng, J. C., Wang, J., & Shraim, A. (2003). A global health problem caused by arsenic from natural sources. *Chemosphere, 52*, pp. 1353–1359.

Rivera, P. (2010). Las perspectivas del manejo del agua urbana en Zacatecas. Primer Congreso Red de Investigadores Sociales Sobre Agua, 18 y 19 de marzo de 2010, Mexico.

Secretaría de Salud (SSA) (2000). Modificación a la Norma Oficial Mexicana NOM-127-SSA1-1994, Salud Ambiental. Agua para Uso y Consumo Humano Límites permisibles de Calidad y Tratamientos a que Debe Someterse el Agua para su Potabilización. Diario Oficial de la Federación Tomo DLXVI No. 15. Miércoles 22 noviembre de 2000.

Secretaría de Salud (SSA) (2003). Modificación a la Norma Oficial Mexicana NOM-040-SSA1-1993, Productos y servicios. Sal yodada y sal yodada fluorurada. Especificaciones sanitarias. Diario Oficial de la Federación Tomo DC No. 16. Martes 23 de septiembre de 2003.

Soto-Rojas, A.E., Urena-Cirett, J.L., Martinez-Mier, L. (2004).A review of the prevalence of dental fluorosis in Mexico. *Revista Panamericana de Salud Publica*. 15(1), pp.9-18.

U.S. Geological Survey (2011). Mineral Commodity Summaries. The data are available in the following link: http://minerals.usgs.gov/minerals/pubs/mcs/#www [06/05/2011].

Vega, S. (2001). Riesgo sanitario ambiental por la presencia de arsénico y fluoruros en los acuíferos de México. Comisión Nacional del Agua, Gerencia del Saneamiento y Calidad del Agua, México D.F.

World Health Organization (WHO) (1984). Guidelines for Drinking-water Quality. Volume 2. Health Criteria and Other Supporting Information. World Health Organization, Geneva.

WHO (1996). Guidelines for Drinking-water Quality. Volume 2. Health Criteria and Other Supporting Information. 2nd edition. World Health Organization, Geneva.

WHO (2001). Environmental Health Criteria 224: arsenic and arsenic compounds. World Health Organization, Geneva.
WHO (2004). Guidelines for Drinking-water Quality. Volume 1. Recommendations. 3rd edition. World Health Organization, Geneva.

WHO (2006). Guidelines for Drinking–water Quality, First addendum to third edition. World Health Organization, Geneva.

Yu, M. (2005). *Environmental Toxicology. Biological and Health Effects of Pollutants.* Boca Raton, FL, CRC Press.

Appendix 1

WTP Question for fluoride

Fluoride occurs commonly in Guadalupe waters. Ingestion of water containing high concentrations of fluoride can provoke dental fluorosis -an unsightly brown mottling of teeth (see picture 1)-. Higher intakes can provoke skeletal fluorosis, which can lead to fractures and crippling skeletal deformity (see picture 2). Fluorosis can manifest itself from childhood with the result that affected individuals cannot work properly and may be economically as well as physically disadvantaged for life. The Secretary of Health through the Mexican Official Norm (NOM-127-SSA1-1994) established a standard level of fluoride in drinking water. This **standard level** is exceeded if the level of fluoride is greater than **1.5 milligrams per litre**.

Monitoring results conducted by the Mexican Institute of Water Technology and the National Autonomous University of Mexico (UNAM) show that two extraction wells in your community water system (San Ramón system) have 3.05 milligrams of fluoride per litre of water extracted (that is twice the standard level). Water samples collected in September 2010 from households in Guadalupe also showed fluoride levels above the standard. Fluoride in tap water cannot be removed by boiling water or using normal household filters available in the market. Using tap water for drinking and/or cooking increases your daily intake of fluoride and the risk of develop dental fluorosis among the household members. Your community could install a new or improved treatment system that would reduce fluoride in tap water from current levels to below the standard level (1.5 mg/l). You could reduce your current bottled water consumption because your tap water would be safe to drink and cook. Children in the community could have normal teeth if the filtration system is installed (see picture 3). **UNRELIABLE: [However, the time you will have access to tap water will remain approximately the same.] RELIABLE: [In addition, you will have tap water 24 hours per day everyday of the year.].** But, since this would involve increased costs, it would be necessary to increase your water bill to support this treatment.

What is the **LARGEST monthly payment ABOVE** your current water bill that you would be willing to make for a new or improved treatment system and its maintenance that would reduce the level of fluoride to below the standard level in your drinking water? ______________

WTP Question for arsenic

Arsenic occurs commonly in Guadalupe waters. Ingestion of water containing high concentrations of arsenic may provoke skin, lung and bladder cancer and other adverse effects. Coetaneous changes due to arsenicosis include melanosis (patchy pigmentation of the skin, see picture 1), hyperkeratosis (thickening of the skin, see picture 2), desquamation and in severe cases gangrene. Anaemia and leucopoenia are highly related with chronic ***As*** exposure. The Secretary of Health through the Mexican Official Norm (NOM-127-SSA1-1994) established a standard level of arsenic in drinking water. This **standard level** is exceeded if the level of fluoride is greater than **0.025 milligrams per litre**.

Monitoring results conducted by the National Autonomous University of Mexico (UNAM) and the University of London show that two extraction wells in your community water system (San Ramón system) have 0.40 and 0.29 milligrams of arsenic per litre of water (that is 16 and 10 times the standard level respectively). Water samples collected from households in Guadalupe also showed arsenic levels above the standard. Arsenic in tap water cannot be removed by boiling water or using normal household filters available in the market. Using tap water for drinking and/or cooking increases your daily intake of arsenic and the risk of develop arsenic related diseases among the household members. Your community could install a new or improved treatment system that would reduce arsenic in tap water from current levels to below the international standard level established by the World Health Organisation (0.01 mg/l) . You could reduce your current bottled water consumption because your tap water would be safe to drink and cook. **UNRELIABLE: [However, the time you will have access to tap water will remain approximately the same.] RELIABLE: [In addition, you will have tap water 24 hours per day everyday of the year.].** But, since this would involve increased costs, it would be necessary to increase your water bill to support this treatment.

What is the **LARGEST monthly payment ABOVE** your current water bill that you would be willing to make for a new or improved treatment system that would reduce the level of fluoride to below the standard level in your drinking water?_____

WTP Question for arsenic

Picture 1 Melanosis

Picture 2 Hyperkeratosis

WTP Question for fluoride

Picture 1 Dental fluorosis

Picture 2 Skeletal fluorosis

Picture 3 Fluorosis effects

Source: Report of the Forum on Fluoridation (2002:126)

Appendix 2

Table 1 Minerals production in Zacatecas

Year	Gold Production (kilograms)	Silver Production (kilograms)	Lead Production (tons)
1995	623.90	952,931	51,613
1996	972.80	957,491	57,556
1997	1,160.00	1,118,868	60,952
1998	1,219.90	1,088,406	50,620
1999	1,208.20	926,401	23,438
2000	1,024.00	928,378	19,351
2001	1,078.80	1,158,578	27,077
2002	1,020.60	1,318,425	41,195
2003	1,002.50	1,333,499	50,274
2004	1,185.90	1,345,130	51,904
2005	1,413.70	1,528,765	52,330
2006	1,441.00	1,477,601	46,359
2007	1,295.50	1,517,185	46,044
2008	1,766.50	1,491,525	43,643
2009	6,099.50	1,627,847	50,972
2010	12,836.70	2,028,766	97,789
2011	17,000.20	2,222,538	125,190

Source: INEGI. Banco de Información Económica 2011

Table 2 Aquifers use

Code	Aquifer	R	NCD	AGC	Deficit
3210	Benito Juárez	20.1	0	21.24	**-1.14**
3225	Calera	83.9	1.3	150.37	**-67.75**
3226	Chupaderos	72.8	0	184.83	**-112.03**
3227	Gpe. Bañuelos	10.7	0	12.65	**-1.95**
All figures are expressed in millions of cubic metres per year. R: Average annual recharge; NCD: Natural committed discharge; AGC: Average groundwater concessions					

Source: CONAGUA (2009)

Table 3 As and F– levels in Guadalupe and Zacatecas extraction wells and households

Sample name	As mg/L	F^- mg/L
San Ramón 8	0.0154	1.26
San Ramón 10	0.0216	1.36
San Ramón 14	0.4072	3.09
San Ramón 16	0.2920	3.05
San Ramón "La Coruña"	0.017	1.30
Bañuelos 3	0.020	1.26
Bañuelos pumping station	0.018	1.09
Guadalupe household 1	0.042	1.72
Guadalupe household 2	0.085	1.45
Zacatecas household 1	0.040	1.57
Zacatecas household 2	0.034	1.63
Bañuelos household 1	0.017	1.27
Bañuelos household 2	0.018	1.28
San Ramón household	0.017	1.35

San Jerónimo household	0.016	1.05
Mexican guideline value	**0.025**	**1.5**

Table 4 Historical As levels in wells 14 and 16

	As mg/L			
Sample name	Mar-94	Nov-94	2002	Sep-10
San Ramón 14	0.4925	0.138	0.463	0.4072
San Ramón 16	0.356	0.155	0.425	0.292
Mexican guideline value: **0.025**				

Source: Castro, Torres, and Iturbe (2003) and Leal, M. and Gelover, S. (2002)

Table 5 Historical F– levels in wells 14 and 16

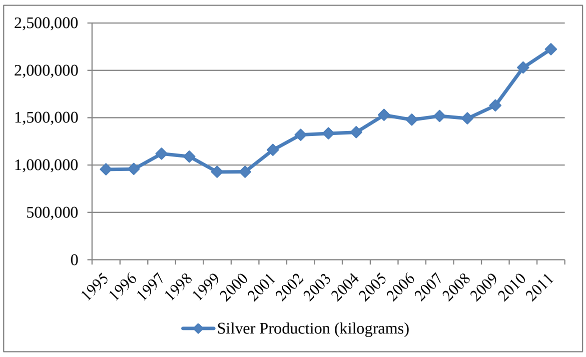
	F^- mg/L	
Sample name	2002	2010
San Ramón 14	2.92	3.09
San Ramón 16	2.96	3.05
Mexican guideline value: **1.5**		

Source: Leal, M. and Gelover, S. (2002)

Table 6 Average profile of sampled respondents

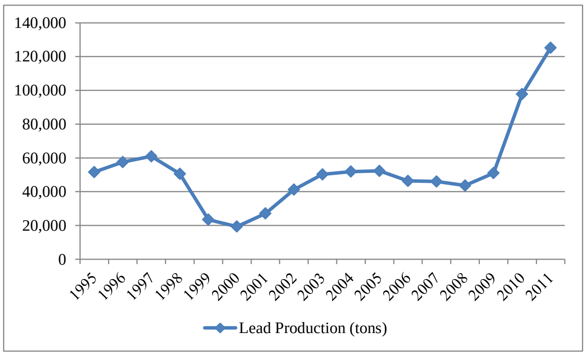
Description	**Mean**	**SD**
Age of the respondent (in years)	38.12	16.72
Percentage of female respondents	48.91	50.12%
Education of the respondent (no. of schooling years)	9.22	4.09
Number of household members	4.48	2.28
Number of children (under 14) in the household	1.03	1.27
Marital status (percentage married)	59.24	49.27%
Monthly household income (Mexican pesos)	4,496.20	6,269.46
Monthly expenditure in food (Mexican pesos)	1,573.22	1,117.08
Monthly expenditure in medicines (Mexican pesos)	170.89	549.61
Monthly expenditure in tap water (Mexican pesos)	91.17	77.59
Monthly expenditure in bottled water (Mexican pesos)	104.12	117.96

Fig 1 Silver Production in Zacatecas



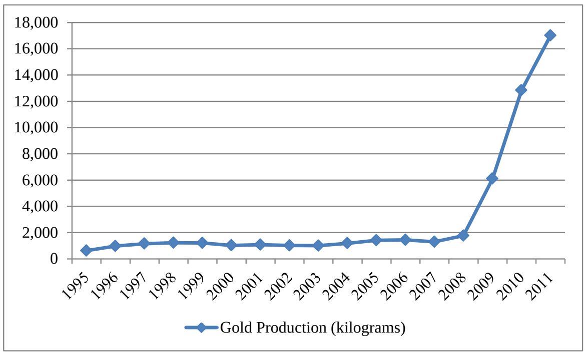
Source: INEGI. Banco de Información Económica 2011

Fig 2 Lead Production in Zacatecas



Source: INEGI. Banco de Información Económica 2011

Fig 3 Gold Production in Zacatecas



Source: INEGI. Banco de Información Económica 2011